APPLICATIONS OF THE μA739 AND μA749 DUAL PREAMPLIFIER INTEGRATED CIRCUITS IN HOME ENTERTAINMENT EQUIPMENT

by David Campbell, Werner Hoeft, and Wes Votipka

INTRODUCTION

The μA739 and μA749 circuits consist of two identical amplifiers with common bias. They are designed as low-cost dual operational amplifiers for general industrial and consumer applications. Three applications for home entertainment are discussed in this paper: a high fidelity phonograph preamplifier, a stereo tape amplifier, and a TV remote control amplifier. The power supply rejection, linearity, low noise, and flexibility of the circuit make it an ideal building block in home entertainment systems.

PHONOGRAPH PREAMPLIFIER

A phono preamplifier circuit must have good signal-to-noise ratio, wide dynamic range, low distortion, good channel separation, and should also be reproducible on a volume basis. The μA739 and the μA749 satisfy these requirements and can be used in phono circuits in a wide variety of configurations to suit individual needs. In the circuits described in this paper, the gain is 40dB at 1kHz, a typical value for phono circuits.

D-C Considerations

With a single power supply, the d-c output voltage should be adjusted so that the maximum signal can be obtained from the amplifier. If equal bias source resistances are used, the d-c operating point will depend on the magnitude of the offset current in the IC and not on the bias current. To reduce both the charge on the coupling capacitors and the size of filter capacitors for the bias network, the plus input of the IC is biased at 10% of the power supply voltage. The d-c gain of the circuit is set at 5 by the feedback to the minus input, thus setting the output at 50% of supply. Both plus inputs are biased from the common bias point to reduce the parts count. In a high fidelity circuit, the ground for the bias circuit should be returned to a good audio ground to eliminate hum from the input. The power supply turn-on and turn-off time constants should be sufficiently long to allow the output capacitor to charge without introducing pops and thumps in the system output.

Allowances should be made in the power supply for current drain fluctuations caused by resistance fluctuations in the IC. These resistance fluctuations (±20%) must not cause the power supply voltage to exceed the maximum allowable voltage (36 volts). The μA749 reduces the severity of this problem. The outputs are uncommitted on this configuration, and the total current drain depends on the tolerance of the resistors used for d-c loads on the output of each half. An additional advantage of the μA749 is that the output current can be set as high as 5 mA so that the IC can drive a lower impedance load.

The μA739 can operate with fewer components if both plus and minus power supplies are used. There are two reasons for this: First, the bias for the plus inputs of the IC are referenced to ground directly, eliminating the need for a bias source with nominally 1 μV of hum from the power supply. Second, the filter requirements for the power supplies are reduced considerably by the power supply rejection of the IC.

With a dual supply, the output swing will be maximum if each side of the μA739 is biased from the same source impedance. Since the feedback is a-c coupled, the d-c gain is unity and the output stays at a nominal zero volts. An additional advantage of this bias is that the capacitors coupling the output, feedback, and input do not charge to large d-c voltages. As a result, turn-on and turn-off thumps are reduced. The choice of 1MΩ bias resistors is based primarily on a-c considerations. (It should be noted that the bias current could cause as much as 2.5 volts drop across these resistors).

Compensation

The amplifier must be compensated for the unity gain that phono circuits have at high frequencies. Since the open loop phase of the μA739 is 180 degrees at 1.5 MHz, the amplifier must have less than unity gain at this frequency. Several methods of shaping the forward gain response will satisfy this requirement, and it is instructive to learn what differences can be expected with different compensating circuits. In the following paragraphs we will describe four different compensations: (1) Normal voltage follower compensation, (2) Second stage compensation, (3) Feedback compensation, and (4) Single component compensation.

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(1) Normal Voltage Follower Compensation

This compensation, shown in Figure 1A, gives the frequency response curve shown in Figure 2A by combining two different compensations:

- Feedback compensation around the output stage of the amplifier
- Loading compensation between the collectors of the input stage of the amplifier.

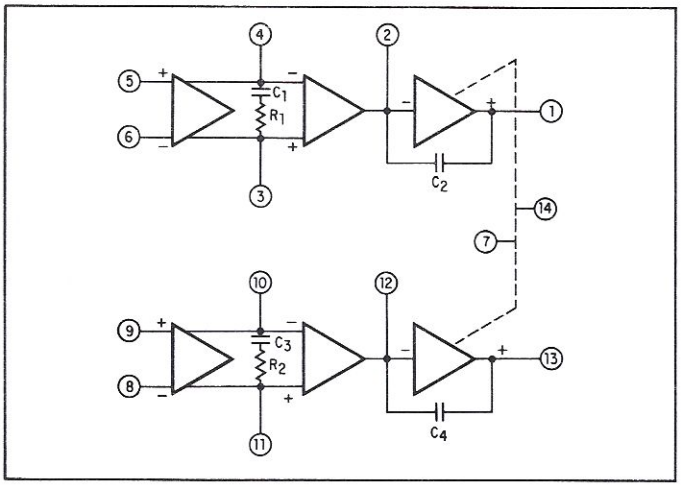

Fig. 1A. Voltage follower compensation.

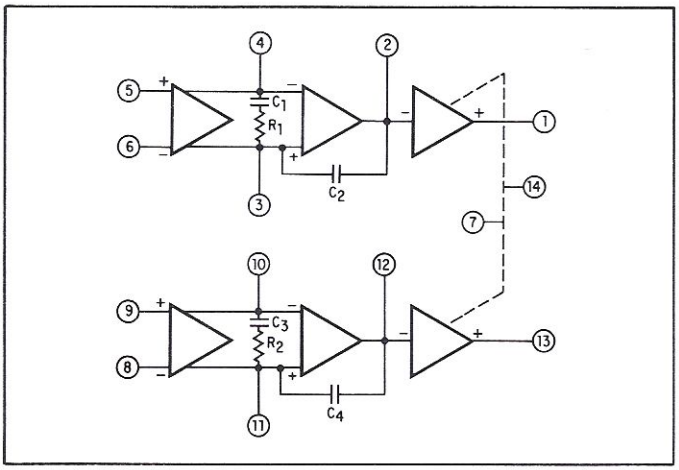

Fig. 1B. Normal phono compensation.

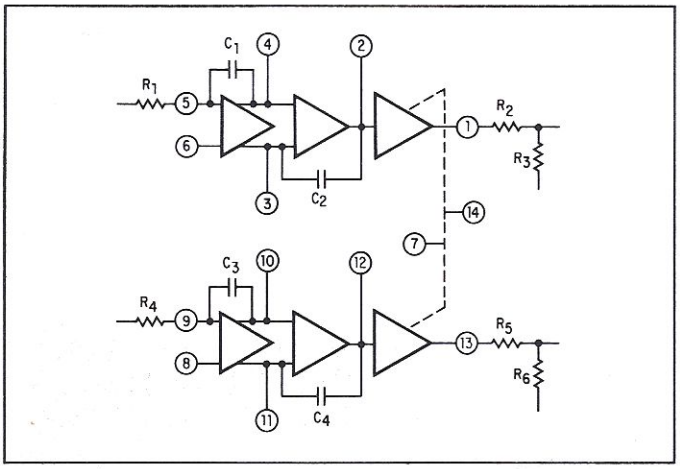

Fig. 1C. Wide band phono compensation.

Figure 2B shows the contribution of each component to the overall compensation of the circuit. The compensation at the input collectors does most of the gain reduction. With the compensation shown, the input R-C network produces 60dB of gain reduction. The output compensation is effective at high frequencies to complete the desired amplitude response.

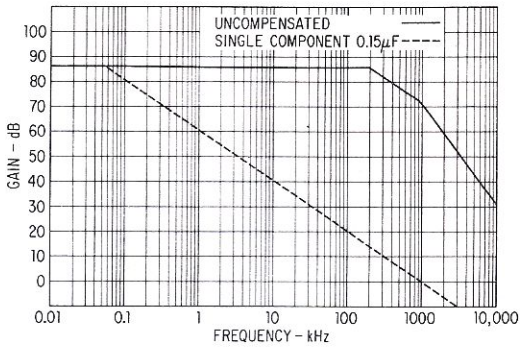

Fig. 2A. Open loop response and simple compensation.

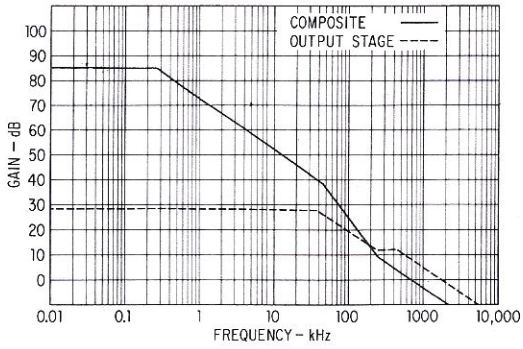

Fig. 2B. Open loop response for voltage follower operation.

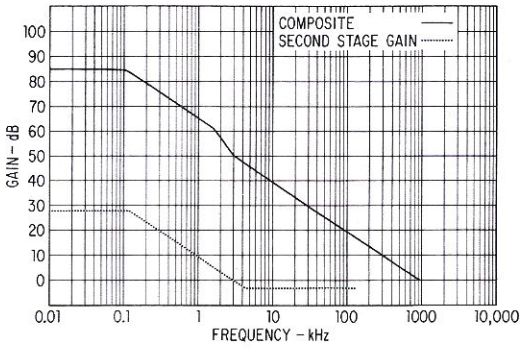

Fig. 2C. Open loop response for normal phono.

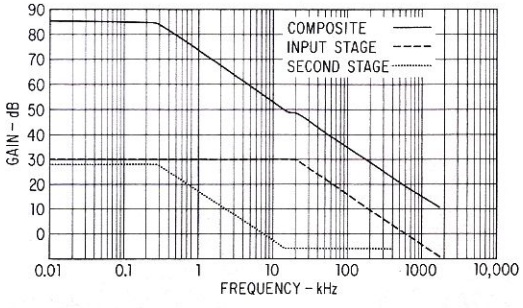

Fig. 2D. Open loop response for maximum slew rate.

Normal voltage follower compensation stabilizes the amplifier for any input and output loading, but it has one peculiarity. When the amplifier is operated at high frequencies, the input stage can no longer supply enough current to the second-stage transistors, and the amplifier is slew-rate limited. For normal unity gain operation, the output rises (or falls) at a rate determined by the component values and the current available. However with phono compensation, the feedback phase is such that the overdrive on the input causes the compensating capacitor C in Figure 1A, to charge in one direction until the capacitor is offset sufficiently to produce an unbalance in the second stage. This unbalance then causes the capacitor to charge in the other direction. Thus the amplifier has a low frequency oscillation superimposed on the signal. An oscillatory condition of this sort will occur in phono circuits for most types of compensation. However, the frequency at which the oscillation starts, as well as its magnitude, can be controlled. A variation on this compensation, in which the output compensation is accomplished by loading the amplifier output with capacitance, is suitable for some applications.

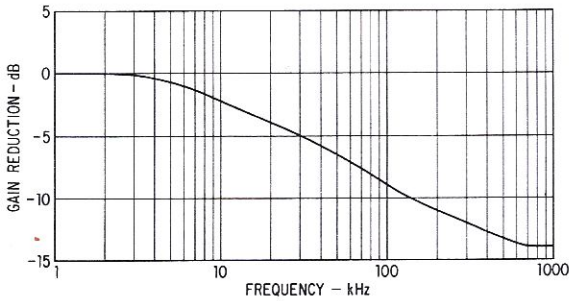

Fig. 3. Reduction of output stage gain due to equalization loading.

Note that the phono equalizing circuit changes the forward response as shown in Figure 3. In a typical application the total compensation inserted by the equalizing network can be used as part of the amplifier compensating network. Changing the impedance level of the feedback equalization eliminates one part from the circuit and also reduces the high frequency output capability. (See the curves of voltage output versus frequency for various compensations shown in Figure 4).

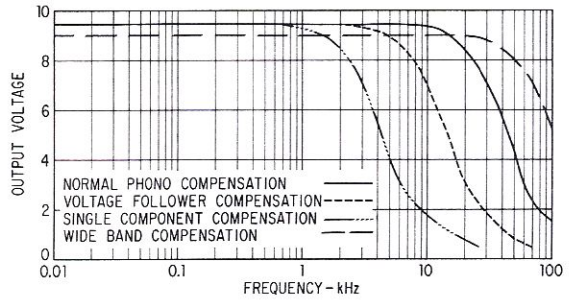

Fig. 4. Output voltage as a function of frequency for various circuits. Harmonic distortion - 1%.

(2) Second Stage Compensation

Feedback compensation around the second stage can bring about an improvement in high-frequency voltage output. This compensation inserts a gain reduction 6dB greater than the gain of the second stage, has only a second order effect on the output capability, and can be easily inserted in the low-frequency spectrum without using large capacitors. The second stage is converted to a voltage follower by means of a capacitor as shown in Figure 1B.

Figure 2C shows the contributions of each compensating section. The R-C combination across the input collectors completes the compensation in a manner similar to that shown in Figure 1A. This type of compensation has two advantages: (1) It results in an amplifier that is stable for any source and load condition. (2) It allows the amplifier to deliver full output to a higher frequency, as shown in Figure 4.

(3) Feedback Stage Compensation

In very high quality phono circuits, full output capability through the entire audio band is desirable but requires additional compensating components. The compensation shown in Figure 1C can give maximum output to beyond 50kHz. In all, five components are required for this configuration whose use is restricted to the μA749 with the uncommitted output collectors. Feedback compensation is used around both the second stage and the first stage. The R-C network on the first stage acts as a Miller integrator to roll off the input stage gain. The resistor in series with the output isolates the amplifier from capacitive loads, and the resistor in series with the feedback equalization isolates the amplifier from the loading of the equalization network. The forward response of the circuit is shown in Figure 2D.

Schematically it would appear that this is a stable unity gain configuration. This would be true if the first stage were in fact an ideal amplifier. But at high frequency (above 1 MHz) the first stage open loop gain decreases, and the feedback capacitor feeds signals through directly from the input. This anomaly makes the role of R_3, the series feedback resistor in Figure 1C, a dual one. (1) It isolates the amplifier output from the capacitive load presented to the feedback. (2) It limits the feedback above 50kHz so that the amplifier has 16dB of gain at high frequency.

For circuits requiring full output to high frequency, this circuit offers a method of obtaining the desired performance. One side benefit of this compensation is the absence of motorboating associated with high-frequency, large-signal operation. By the time the amplifier becomes slew-rate limited, the feedback signal is in phase with the output and the capacitors charge equally on both halves of the signal cycle. The output in the audio band is slightly lower owing to the voltage drop across R_2 in Figure 1C, as is seen in Figure 4.

(4) Single Component Compensation

In some equipment the output is connected to a known load, and the input has a known source impedance. The μA739 can be used in these systems by compensating only at the input collectors. The amount of compensation inserted by the network at the input collectors is determined by the total impedance of the network between the collectors. If the total contact resistance plus the capacitor ESR is two ohms, the network will insert 80dB of attenuation. This attenuation, together with the compensation inserted by the equalizing network, gives stable operation in a fairly broad range of source and load impedances. This compensation is advantageous in systems that are sensitive to total component count and total cost.

Noise Performance

The noise output from a phono circuit is a function of the equivalent input noise and the gain. For any compensation, the audio passband (10Hz to 10kHz) noise must by definition be the same for the same gain and same terminating impedances. One would expect that the audio passband noise and compensation are independent, as indeed they are. However, if the noise is measured on a wide band meter, then the out-of-passband noise -- 1/f noise and high frequency noise -- does in fact differ for different compensations.

1/f noise is a function of the low frequency terminating impedance and the low frequency gain. The phono feedback arrangement has a gain vs frequency response shown in Figure 5. The components might vary in different systems, but the shape is relatively fixed for the application. Hence the low frequency noise is dependent on the value of the input capacitor.

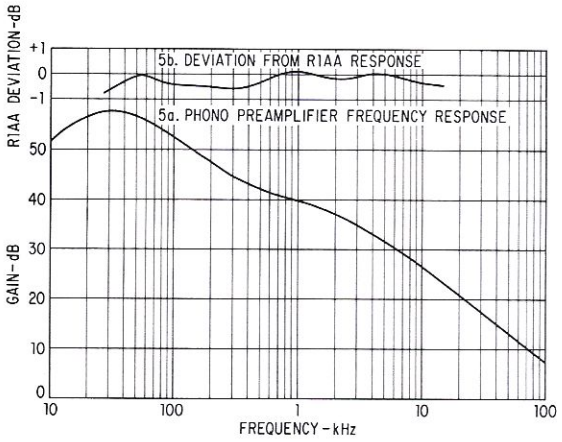

Fig. 5

High frequency noise output depends on the phase margin of the amplifier. The amplifier, when connected as a phono amplifier with 40dB of 1kHz gain as shown, will have unity gain at about 200kHz. Peaking of the response at high frequency will cause noise output in a narrow band about the peaking frequency.

TABLE I.
Noise Outputs and Phase Margins for Three Circuits

CIRCUIT	WIDE BAND NOISE	PHASE MARGIN	AUDIO PASSBAND NOISE
1A	550 μV	25°	120 μV
1B	220 μV	70°	120 μV
1C	130 μV	90°	120 μV

The variation in wide band noise output, shown in Table 1, demonstrates the differences in high frequency peaking. Audio passband noise output from 20Hz to 20kHz is, as expected, the same for all compensations. However wide band noise is not constant and in fact is a function of phase margin. The dependence of wide band noise on phase margin is shown in Table 1. Note that the circuit in Figure 1C, which has the largest gain bandwidth product, has the lowest wide band noise output. This is another indication that the high frequency noise is a function of phase margin rather than high frequency noise figure.

A key feature of the μA739/μA749 is an input noise as low as the input noise in the best discrete designs. Typical performance of 1.2μV input noise gives signal-to-noise ratios of 78dB for 40dB 1kHz gain.

Linearity

Figure 6 shows plots of distortion versus frequency for the phono circuit. The μA739/μA749 has considerably less distortion (typically <0.1%) than discrete designs.

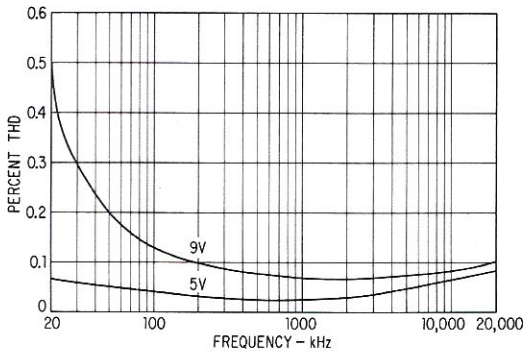

Fig. 6. Distortion vs frequency @ V_O = 5V + 9V.

Comments

The μA739 or the μA749 can be used in a wide range of phono circuits. The flexibility of operating supplies and compensation networks makes the μA739/μA749 suitable for any phonograph requirement. This flexibility, along with low cost, gives the user a wide range of system applications for the μA739 and μA749. Complete schematics for stereo phono pre-amplifiers are shown in Figures 7A, B, and C.

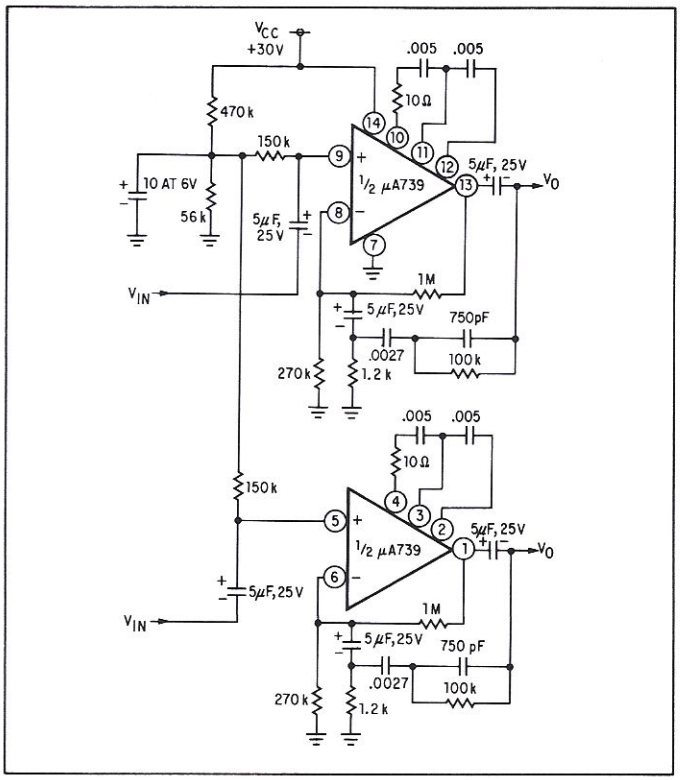

Fig. 7A. Phono preamp single supply.

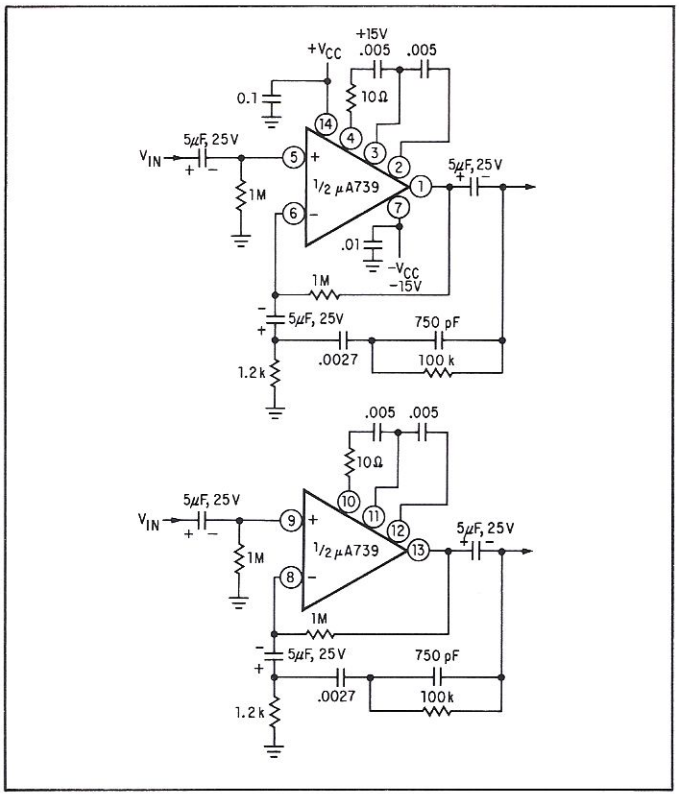

Fig. 7B. Phono preamp dual supply.

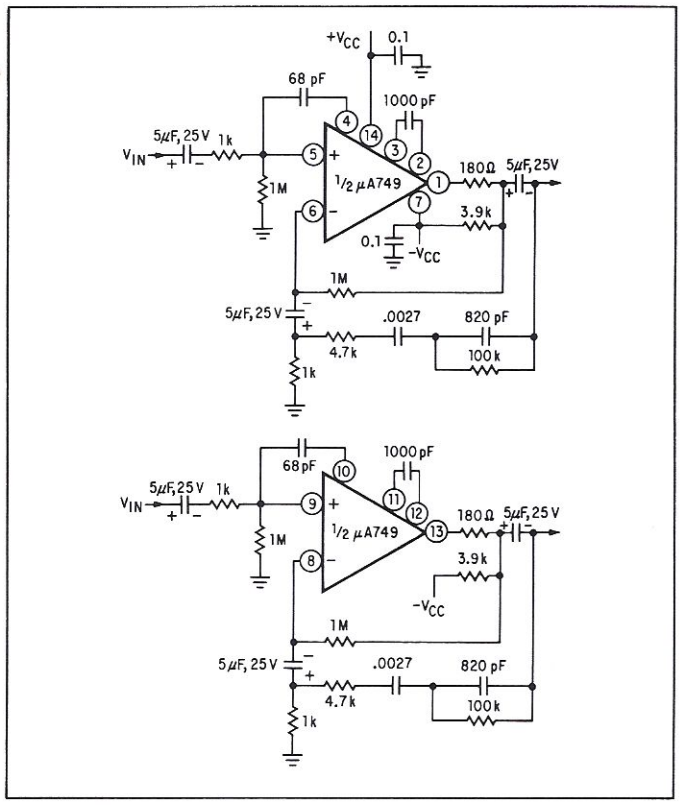

Fig. 7C. Phono preamp wide band.

Stereo Tape Amplifier

Tape deck amplifiers for cartridge tape systems must have high gain and good signal-to-noise ratio. The dynamic range requirement is not severe, but the recording level is usually so low (typically 200 μV), that interference from tape motors, power supply circuits, and switching circuits often influence performance. The μA749 minimizes the problems associated with extraneous signals in the amplifier input, and in general performs better than discrete designs.

Circuit Description

D-C Biasing

The schematic is shown in Figure 8. R_1 and C_1 are power supply decoupling for the circuit. Since the power supply rejection of the μA749 is typically 80dB, no further filtering is needed for the supply. R_2, R_3, and C_2 bias the plus input of the μA749. The bias current for the input (less than 2.5μA) flows through the playback heads. R_6 and R_7 bias the minus input with feedback from the output of each amplifier. R_{10} and R_{11} are the collector loads to ground for the output stage.

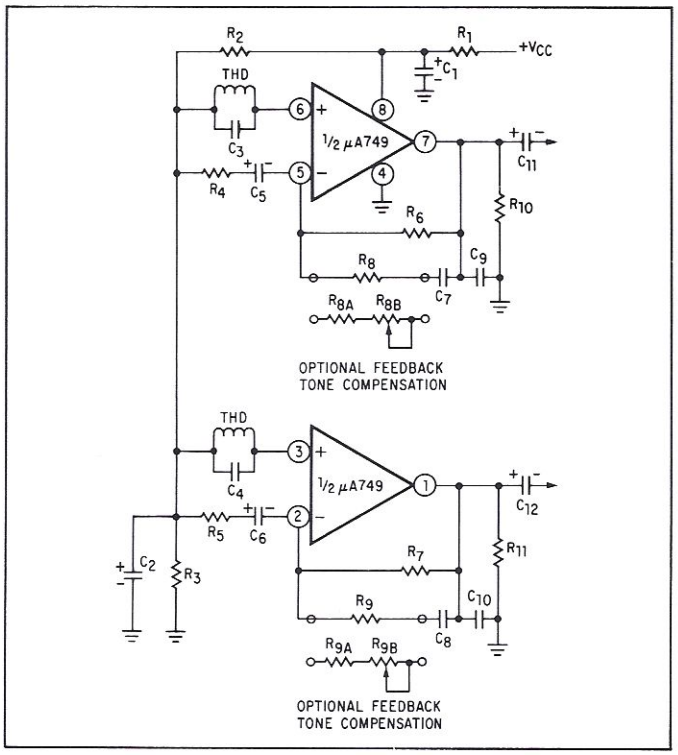

Fig. 8. Tape preamp.

Compensation

Compensation for each amplifier is provided by C_3, C_4, C_9, and C_{10}. The output compensation, C_9 and C_{10}, rolls the amplifier open loop gain off to insure stability with tape equalization. C_3 and C_4 terminate the tape head and provide a low source impedance for the plus inputs at frequencies above the audio passband.

A-C Considerations

The gain and playback equalization are fixed by the feedback components R_4, R_5; C_5, C_6, R_6, R_7; C_7, C_8; R_8, R_9. The value of C_5, C_6 and R_4, R_5 determine the low frequency rolloff below 50Hz. The shape of the equalization is established by R_6, C_7, R_8, and R_7, C_8, R_9. R_8 and R_9 can be used as tone control pots as shown in Figure 8 if there is sufficient compensation to insure

stability of the amplifier in the full cut position. Two sets of values are listed in Table 2 for different closed loop gains. Both sets of values are for nominal 13-volt battery operation.

TABLE II
Values for Tape Amplifier

50H A_V	CIRCUIT 1 75 dB	CIRCUIT 2 65 dB
R_1	220	220
R_2	1.5M	1M
R_3	1.5M	1M
R_4	100	270
R_5	100	270
R_6	1.5M	1M
R_7	1.5M	1M
R_8	33k	22k
R_9	33k	22k
R_{10}	10k	4.7k
R_{11}	10k	4.7k
C_1	250μF, 15 V	250μF, 15 V
C_2	1μF, 15V	1μF, 15 V
C_3	470 pF	470 pF
C_4	470 pF	470 pF, μF
C_5	25μF, 3 V	5 μF, 3 V
C_6	25 μF, 3 V	5 μF, 3 V
C_7	.002 μF	.0015 μF
C_8	.002 μF	.0015 μF
C_9	.0047 μF	.0047 μF
C_{10}	.0047 μF	.0047 μF
C_{11}	5μF, 15 V	5 μF, 15 V
C_{12}	5μF, 15 V	5 μF, 15 V

Circuit Performance

The frequency response of a tape circuit is shown in Figure 9. Feedback equalization makes the response uniform for variation in supply voltage, temperature, etc.

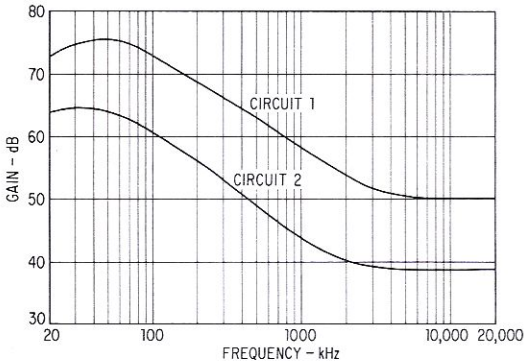

Fig. 9. Tape preamp frequency response.

Harmonic distortion is plotted in Figure 10. The high output capability and high gain of the μA749 give the user a choice of operating gains up to 75dB at 50Hz. The signal-to-noise ratio for the amplifier is typically 55dB (bandwidth 50Hz to 10kHz, reference level 200 μV at 4000Hz). The common mode rejection of the μA749 reduces motor hum, switching transients, etc. by 75dB. Frequency response is changed less than 0.25dB by variation in power supply voltage from 10V to 16V.

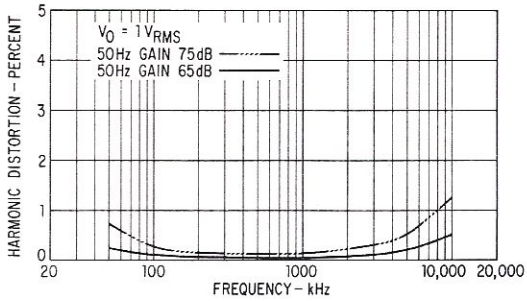

Fig. 10A. Harmonic distortion as a function of frequency.

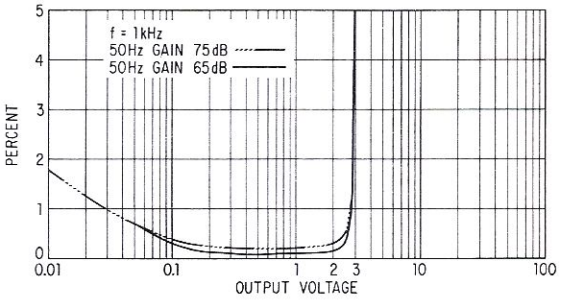

Fig. 10B. Harmonic distortion as a function of output voltage.

TV REMOTE CONTROL RECEIVER

General Description

The TV remote control receiver consists of a high gain amplifier, a transformer and coil for selectivity, and a relay driver. The signal from the transmitter is detected by a condensor microphone and fed to the amplifier. This amplifier must have high gain and low noise, and the μA749 connected in cascade satisfies both these requirements. After amplification, the signal is applied to the base of the relay driver through a frequency-selective output transformer. The amplified and rectified signal activates the relay. Since the signal strength is a function of the position of the transmitter with respect to the receiver, operation must be maintained for a wide range of signals. The performance must be unaffected by fluctuations in line voltage or temperature.

Circuit Description

The operating point of the μA749 shown in Figure 11 is established by the d-c bias network R_1, R_3 and C_3, feeding the plus input through R_2. A feedback loop from the output of the first amplifier through R_5 to the minus input completes the bias and also stabilizes the operating point. The second amplifier is direct-coupled to the first. The minus input of the second amplifier is biased in the same way as in the first amplifier through R_8. R_6 and R_9, the load resistors of the two outputs, set up the quiescent current of the output stages of each amplifier.

Compensation

The capacitors C_5 and C_7 (from the output of each amplifier to ground) provide the compensation for stability and optimum frequency response of each amplifier section.

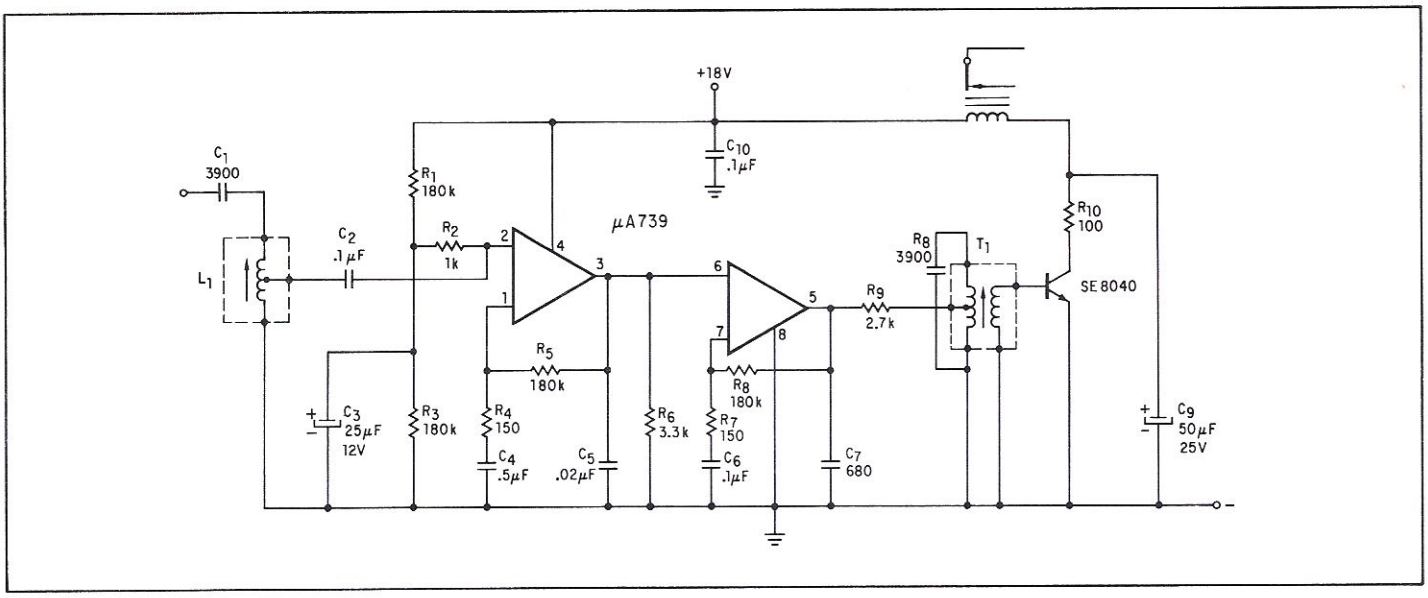

Fig. 11. TV remote control receiver.

A-C Considerations

Figures 12A and 12B show the untuned frequency response. The frequency range in this circuit is 8kHz to 60kHz, and the operating range of the tuned circuits is 20kHz to 50kHz. In order to minimize the noise output and leave the frequencies above 20 kHz unaffected, the frequency response has been rolled off below 10kHz.

Due to the low output impedance of the amplifier, the output transformer is driven through load resistor R_9. This arrangement gives an optimum signal-to-noise ratio. A mismatch of the output of the second stage into the output transformer causes a 15dB loss in the overall gain but results in a lighter loading of the transformer, a higher Q, and a better signal-to-noise ratio.

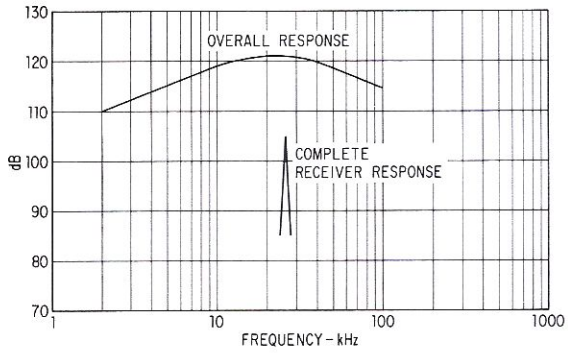

Fig. 12A. TV remote control amplifier.

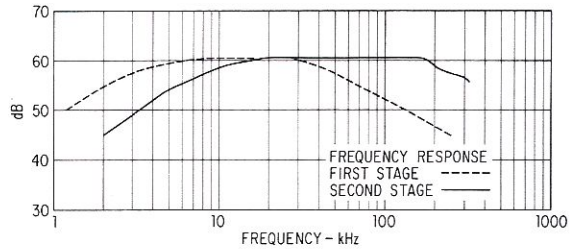

Fig. 12B. TV remote control amplifier.

Circuit Performance

The performance of the circuit satisfies all requirements for reliable operation. It has excellent signal-to-noise ratio and high sensitivity over a wide range of temperature and supply voltages. Table 3 gives the performance measurements of the receiver.

TABLE III.
T.V. Remote Control Receiver.

Gain at 25 kHz	121dB	without tuned circuits
Gain at 25 kHz	121.6dB	at 0°C
Gain at 25 kHz	120.2dB	at 70°C
Gain at 25 kHz	105dB	with tuned circuits, measured at base of relay trans.
Sensitivity for		
relay on at 26 kHz	4μV	18 V supply
relay off at 26 kHz	5.1μV	18 V supply
relay on at 26 kHz	5μV	14 V supply
relay off at 26 kHz	7.8μV	14 V supply
relay on at 26 kHz	4μV	24 V supply
relay off at 26 kHz	5.1μV	24 V supply
Noise output	25mV	measured at the base of relay transistor.
Bandwidth 3dB	1kHz	
S/N Ratio	25dB	at sensitivity Level

T_1 L = 10mH, Q loaded = 35, Turns ratio = 1:15, Tap at 15% — L_1 = 10mH, Tap at 15% — Magnavox #360964-1

Magnavox #360944-1 or equivalent

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